INEEL/CON-02-00158
PREPRINT

Idaho National Engineering and Environmental Laboratory

Expanding the Allowable TRUPACT-II Payload

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August 4, 2002 – August 8, 2002

Spectrum 2002

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Abstract

The partnership between the Carlsbad Field Office (CBFO) and the TRU & Mixed Waste Focus Area (TMFA) was rewarded when several long-term projects came to fruition. The Nuclear Regulatory Commission (NRC) removed some of the conservatism in the TRUPACT-II Safety Analysis Report for Packaging (SARP) with their approval of Revision 19. The SARP strictly limits the payload constituents to ensure that hydrogen gas and other flammable volatile organic compounds (VOCs) don't build up to flammable/explosive levels while the transuranic (TRU) waste is sealed in the container during shipment. The CBFO/TMFA development program was based on laboratory experiments with surrogate waste materials, real waste experiments, and theoretical modeling that were used to justify payload expansion. Future work to expand the shipping envelope of the TRUPACT-II focuses on increasing the throughput through the waste certification process and reducing the waste operations costs by removing the need for a repackaging and/or treatment capability or reducing the size of the needed repackaging/treatment capability.

I. INTRODUCTION

The partnership between the CBFO and the TMFA was rewarded when several long-term projects came to fruition. The NRC removed some of the conservatism in the TRUPACT-II SARP with their approval of Revision 19. The SARP strictly limits the payload constituents to ensure that hydrogen gas and other flammable VOCs don't build up to flammable/explosive levels while the TRU waste is sealed in the container during shipment.

The TRUPACT-II SARP utilized worst-case calculations in the development of the shipping tables. Prior to Revision 19, these SARP worst-case calculations in combination with the approach used to demonstrating compliance with the flammable gas limits, resulted in a significant fraction of TRU waste that was non-shippable in the TRUPACT-II. The three problems that had to be addressed were 1) waste that was predicted to exceed the flammable gas limit when, in fact, it was less, 2) waste that exceeded the flammable gas limit, and 3) waste that exceeds the flammable VOC limit. The two options that exist to address these problems are gas generation testing as described in the TRUPACT-II SARP or waste form modification via repackaging and/or treatment. Both are costly (both time and funds) solutions to the shipping problem.

The CBFO/TMFA designed a development program, based on laboratory experiments with surrogate waste materials, real waste experiments, and theoretical modeling, that removes much of the conservatism in identifying the gas generating potential of the TRUwastes. In 2000, CBFO integrated several of the program elements into the Revision 19 regulatory submittal. It is estimated that Revision 19 increases the amount of contact-handled TRU waste that is shippable in the TRUPACT-II by approximately 94%, assuming that the waste meets all other shipping requirements.

II. THE PROBLEM

The NRC has imposed flammable gas concentration limits on TRU waste transported using the TRUPACT-II and 72-B shipping casks, to minimize the potential for loss of containment during transport. Two primary limits imposed by the NRC are: 1) the concentration of flammable gases, i.e. hydrogen and methane, must not exceed 5 percent (by volume) in the payload and 2) the gas phase concentration of flammable VOCs in the payload must be less than 0.05% (500 ppm). These limits must be complied with for 60 days, the shipping period established in the TRPACT-II SARP. Flammable gases are generated during transport due to radiolysis of hydrogeneous materials, therefore the concentration at the end of the 60-day shipping period must be predicted. Flammable VOCs are not generated during transport therefore the headspace payload concentration remains approximately the same before, during and after transport.

Worst-case calculations were used to establish the wattage limit tables in the SARP, which resulted in approximately 35% of the waste stored at the INEEL, RFETS, and LANL, and a significantly greater fraction at the SRS, not being transportable using the TRUPACT-II. Two options exist to address these rejected drums: gas generation testing as described in the TRUPACT-II and 72-B SARPs, or waste form modification via repackaging and/or treatment.

III. WORK DESCRIPTION

The TMFA activities that were used by CBFO to support Revision 19 included the development of more representative "G" values, development of drum age criteria, and development support for an alternative method for demonstrating compliance with shipping requirements.

II.A. Representative "G" values

The Matrix Depletion Program (MDP) was a three-year joint effort by the CBFO and the TMFA with the objective of investigating the phenomenon of matrix depletion and arriving at dose dependent G-values for contact-handled (CH) TRU waste material types. An effective G-value is the gas generation potential of a specific material or matrix due to exposure to ionizing radiation.

Matrix depletion is the reduction in the effective G-value of a target material with increasing dose. The basis for this phenomenon is that the chemical composition of a hydrogenous material is altered due to interaction with alpha particles. Interaction of alpha particles with hydrogenous materials (e.g. cellulosics and plastics) results in reactions (free radical) that generate flammable gaseous products. Due to the short mean free path of alpha particles in air (~4.2 cm) and the waste matrix (~5×10^{-3} cm), the matrix in the vicinity of alpha emitting radionuclides becomes depleted of hydrogen and subsequent alpha particle deposition results in lower hydrogen gas generation.

To understand and document the matrix depletion phenomena, the MDP was designed with three components: laboratory experiments, real waste experiments, and theoretical modeling.[1] Controlled simulated waste experiments were completed to assess the effective G-value as a function of dose for several waste matrices and the effects of experimental conditions (e.g. isotope, heating, etc.). The results were used to determine a conservative dose dependent effective G-value by waste type. The real waste experiments were completed to show that the MDP dose dependent G-values are conservative estimators of actual waste material type effective G-values. Theoretical analyses was then completed using a numerical model that calculates effective G-value as a function of dose. The analyses was used to show that the current understanding of the fundamental nuclear and molecular mechanisms that result in hydrogen gas generation yield results that are consistent with experimental measurements.

The MDP results provide a three- to five-fold increase in the allowable-wattage limit in the TRUPACT-II for applicable CH-TRU waste drums. This allows for the certification of waste for shipment that would otherwise require treatment to remove hydrogenous material or repackaging of the container into one or more additional drums.

II.B. Drum Age Criteria

The TMFA supported the calculation of drum age criteria (DAC) and associated prediction factors for use with TRU waste[2]. An age criterion must be met by a drum of TRU waste in order for headspace gas samples to be either representative of gases in the drum or appropriate to use in predicting innermost bag VOC gas phase concentration. The DAC establishes the time after waste packaging necessary to wait prior to drum headspace sampling to help ensure that the headspace sample analyses are 90% of steady-state concentration. This project allowed for calculation of specific DACs for the sites. The conclusions from this program resulted in a reduction in the waiting period from 225 days or 147 days (waste type dependent) to as low as a few days for applicable waste configurations. This modification will significantly increase the waste throughput in site waste certification programs.

II.C. Alternative Method for Demonstrating Compliance with Shipping Limitations

To demonstrate compliance (pre-Revision 19) with the 5% flammable gas concentration limit, theoretical worst-case calculations were performed to establish allowable flammable gas generation rates for each shipping category. Allowable decay heat (wattage) limits were then calculated for each shipping category by combining the allowable flammable gas generation rates with the G-value for the waste material having the highest potential for flammable gas generation.

To calculate the decay heat, the current approach is to determine the container isotopic inventory from NDA measurement and calculate the container specific decay heat. This decay heat, including the error, is compared to the TRUPACT-II decay heat limit. If the sum of the calculated decay heat plus the error is below the decay heat limit for the shipping category of the container, the container can be shipped in a TRUPACT-II.

Using this approach, a portion of the waste will exceed the container decay heat limits (even with the realistic G-values determined through the MDP) and cannot be shipped because the decay heat limits are based on the assumption that the highest flammable gas generating material in the container is receiving all the radiation and generating all of the gas. In reality, only a small fraction of the worst-case material will be irradiated. Headspace gas sampling from over 1000 waste drums showed the average concentration of flammable gases in the drums to be low (~0.05%), which indicates that actual flammable gas concentrations are only a fraction of the allowable limits. However, if the drums failed to meet the decay heat limits established for its shipping category, the only recourse would be treatment or repackaging to make the containers shippable.

The objective of the alternate method program was to develop a gas generation rate compliance method that is based on flammable gas headspace measurement. The methodology is based on sampling the waste container headspace for flammable gases, calculating the flammable gas generation rate, and comparing the rate to existing allowable flammable gas generation rate limits[3]. This method uses a parameter (the flammable gas concentration) that can be measured with greater confidence (lower measurement error) than decay heat to determine whether the container meets shipping requirements. This provides the additional benefit that a lower error is used to define the upper confidence level with which to compare the allowable limit.

Use of the alternate methodology addressed those wastes that were predicted to be three to ten times over the wattage limits (pre-Revision 19 limits).

II.D. Future Planned Work

The TMFA is continuing to fund programs that expand the TRUPACT-II shipping envelope this fiscal year. The program elements that are funded include: the demonstration of hydrogen gas getters, demonstration of a technique(s) to breach the waste container's inner bags, development/demonstration of technique(s) to remove the hydrogen stored in organic sludge drums, and demonstration of processes to treat any remaining problematic wastes. The CBFO provides technical review and guidance for these programs and will be responsible for completing the necessary regulatory changes to support implementation.

IV. CONCLUSIONS

The desired end-state of the Waste Isolation Pilot Plant transportation system is to have a transportation system that will minimize the need for repackaging and/or treatment to meet shipping requirements. With the NRC approval of Revision 19 of the TRUPACT-II SARP, a large step was taken to reach this desired end-state. Future Revisions of the SARP will continue to expand the shipping envelope of the TRUPACT-II, which will result in increased throughput through the waste certification process (by minimizing the need to repackage/treat) and reduce the waste operations costs (by removing the need for repackaging/treatment capability or reducing the size of the repackaging/treatment capability).

V. REFERENCES

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